

BEHAVIOR ADAPTATION TO CAR IMPROVEMENT

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ABSTRACT

Compared to cars designed in the 80^{ies} or in the early 90^{ies}, new cars exhibit major improvements, especially in terms of driver assistance and road handling. To quantify the influence of these developments on drivers' behavior, a study was carried out on a test track with two cars of different generations in the summer 2004.

36 male drivers, from 28 to 52 years old, were recruited in the general public to participate to the experiment. They were dispatched in two homogenous groups. For each group, drivers were asked to drive twice the same car: the first time, they familiarized freely with the car and the road during about one hour ("free driving phase"); three weeks later, they were invited to drive on the same road as if they were late or in a hurry ("rush driving phase"). The track is divided in two portions: a "main road" (3.5 km) and a "secondary sinuous road" (1.9 km). There is no traffic on the test track. Drivers' actions on the car's controls were recorded and synchronized with dynamic parameters and video recordings.

This paper is focused on the influence of car modernity and driving consigns on longitudinal and lateral solicitations of the car. Driver's behavior is analyzed in terms of longitudinal acceleration, deceleration (braking) and lateral acceleration when negotiating short curves.

Key words: driver behavior adaptation, longitudinal acceleration, lateral acceleration, ESP, test track, normal driving, emergency driving

INTRODUCTION

Most previous studies focused on the effect of one driving assistance systems and tend to compare driver's behavior with and without the system. The originality of our research is that it takes into account not only the global effect of cars' improvements (road handling, vehicle chassis including steering wheel assistance, suspension, braking, soundproofing...), but also drivers'

"psychological" effects (anticipated confidence, external aspect, dimension of the tires...) before and during driving.

The effect of cars' improvement on driver's behavior is not usually quantified. Only a few studies were carried out around this important topic. For example, Stein Fosser [1] has studied some effects of particular measures to improve safety, like Antilock Braking Systems (ABS) or airbags. He presumed that such systems *produce changes in behavior that reduce the effects of the measures or counteract them entirely. The behavior adaptation that follows such measures is often termed "risk compensation" and it can partly or completely offset the intended safety effects of measures.* In this same study, the author showed the importance of being, or not, aware of the safety measure on someone's car (for example, airbags) which would be more important than the measure's feedback (for example, ABS on a slippery road in terms of steering performance and braking).

New cars exhibit major improvements in terms of driver assistance and road handling. To quantify the influence of these developments on drivers' behavior, a study was carried out on a test track with two cars of different generations: Renault MEGANE 1 and Renault MEGANE 2 (Figure 1) are chosen as an example of cars of 90^{ies} and 2000^{ies}. The two vehicles have almost the same power to mass ratio. By observing several driving measures on these cars, it is possible to compare the use of them by two homogenous groups of drivers. Each subject drives one car twice.



Renault MEGANE 1
(old vehicle)



Renault MEGANE 2
(recent vehicle)

Figure 1. Two experimented cars

MATERIALS AND METHODS

Even this study is related to the effect of car improvement on driver behavior in general, accidentological stake concerning lateral control of vehicles has guided some choices in the experimental protocol. For example, in France, Loss of control-induced accidents represent 20 % of personal injury accidents. This rate is close to 40 % in curves [2]. A statistical study conducted recently by the LAB using real-world accident database [3] showed that in accidents with only one vehicle:

- drivers having 25-54 years old represent 52 % of accidents,
- male drivers are implicated in 76 % of the cases,
- 69 % of accidents happen out of agglomerations,
- for this kind of accidents, 10 % are fatalities and 80 % are injured (20 % severely).

This information is needed for example in the choice of drivers' population, test track characteristics...

Test track driving

To be able to compare the effect of car developments on drivers' behavior, the track was the same for all of them. The road has a length of 5.4 km - 3.5 km "main road" and 1.9 km "secondary sinuous forest road" (Figure 2). Straight lines have a maximum length of 350 m and short curves have radius from 30 m to 200 m. For safety reasons, there is no traffic on the test track.

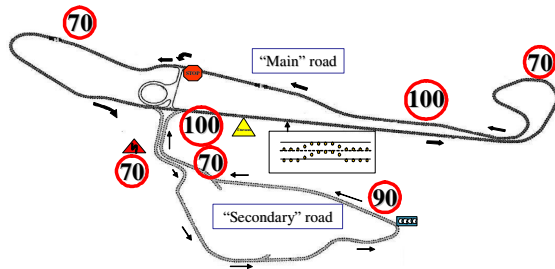


Figure 2. Test Track

- Main road (3.5 km): Figure 3 and Figure 4
- Secondary road (1.9 km): Figure 5 and Figure 6.



Figure 3. Main straight road



Figure 4. Main sinuous road



Figure 5. Secondary sinuous road



Figure 6. Secondary sinuous road

Test vehicles

The vehicles chosen for the experiment were MEGANE 1 and MEGANE 2. MEGANE 1, produced in 1998 (approximately 8 years old) is selected as an "old" car and MEGANE 2 produced in 2004, is selected as a "recent" car. Both cars have ABS. The recent one also has ESP (Electronic Stability Program). The power of general two cars is 66kW (137Nm) and 83kW (152Nm) respectively and engine capacity of both of them is 1.6L. "General performance" ¹ is 140. The general performance of recent car is 150, 7 % higher than old car.

Table 1.
Test Vehicles characteristics

	MEGANE 1	MEGANE 2
Birth	1998(8 years old)	2004
Mileage	55000 km	3000 km
Engine capacity	1.6L	1.6L
Power	66kW / 137Nm	83kW / 152Nm
Equipment	Air conditioning +ABS	Air conditioning+ ABS + ESP
General performance	140	150 (+7%)

Embedded sensors allow to measure drivers' actions on the car's controls (steering wheel and pedals). These measures are recorded and synchronized with dynamic parameters (speed, accelerations...) and video recordings. Four

¹ criterion based on tire characteristics, aerodynamic, maximum speed and time to run 100, 400 or 1000m..., and used by Renault dynamic experts

cameras and a microphone record events taking place inside the car and on the road.

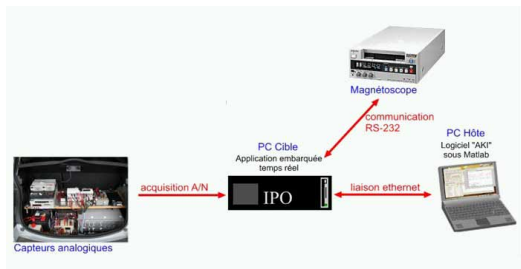


Figure 7. Instrumentation of MEGANE 1 (old vehicle)

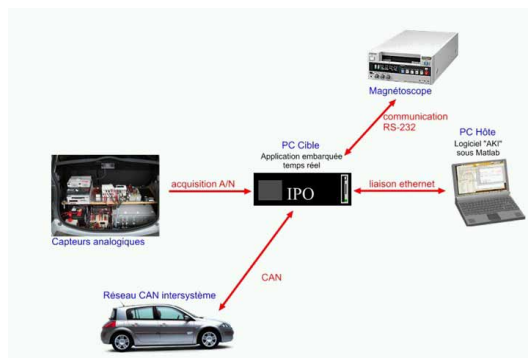


Figure 8. Instrumentation of MEGANE 2 (recent vehicle)



Figure 9. Example of driving video recording

Drivers

36 male drivers (volunteers) participated in the experiment. They were recruited according to their age, driving license acquisition year and annual mileage so as to be representative of drivers involved in loss of car control accidents in France. Their ages vary between 28 and 52 years old (Table 2). The license years vary between 10 and 24 years (median of 19 years), and their annual mileage is between 2000 and 32500 km a year (average of 17000 km). The sample is divided into two homogeneous groups: nineteen (19) volunteers of group 1 were asked to drive MEGANE 1 and

seventeen (17) volunteers of group 2 were asked to drive MEGANE 2.

In all the Tables, Group 1 means old car (MEGANE 1), Group 2 means recent car (MEGANE 2).

Table 2.
Drivers' characteristics

	Age (year)		Driving License (year)		Annual miles (km/year)	
Group	G1	G2	G1	G2	G1	G2
Minimum	29	28	18	10	2000	2000
Maximum	52	52	24	23	32500	25000
Medium	39	39	19	19	20000	16500

Experimental protocol

After brief questionnaire and alcohol test, each group is asked respectively to drive MEGANE 1 and MEGANE 2. Each group drives twice respectively. At the first time, they are asked to drive freely to be familiarized with the car. They are free to choose their driving rhythm ("free driving phase"). In this phase, they drive first lap without data acquisition, and then they have one hour for normal driving with a short rest (30 seconds) after each lap. This phase allows us to collect enough data on the driving style and physical state of the subject.

Three weeks later, they were invited to drive on the same road as if they were late or in a hurry ("rush driving phase"): they had to drive on the same track with a temporal objective they did chose. They have not to take unmeasured risk. This phase allow to see what margin they keep when negotiating curves, and how they will accelerate/decelerate in straight road. They were asked to drive 3 laps 3 times (a short rest after every 3 laps). In conclusion, all subjects drove about 16 laps with data acquisition: **7 laps** for "free driving phase" and **9 laps** for "rush driving phase". At the end of the task, they were interviewed by a psychologist about their feelings and their driving experience.

DEFINITION OF VARIABLES

Variables can be divided into two dynamics groups: speed and acceleration. Acceleration variables can be divided in two groups: longitudinal and transversal acceleration variables (Figure 10). Both longitudinal and transversal acceleration are measured. All variables are calculated for each subject and for **each lap**. This paper is focused on eleven variables:

(Longitudinal) Speed variables

- $V_{moyTour}$: average speed (by lap)
- V_{moyLD} : straight road average speed
- V_{moyVG} : curve road average speed

Longitudinal acceleration variables

- ALPerc80: longitudinal acceleration 80percentile
- AccelMax: maximum longitudinal acceleration

Longitudinal deceleration variables (braking)

- ALPerc8: longitudinal acceleration 8 percentile
- DecelMax: maximum deceleration

Transversal acceleration variables

- ATPerc92: transversal acceleration 92 percentile (left turn)
- ATMaxG: maximum transversal acceleration (left turn)
- ATPerc4: transversal acceleration 4 percentile (right turn). It corresponds also to 96 percentile if absolute values are considered
- ATMaxD: maximum transversal acceleration (right turn).

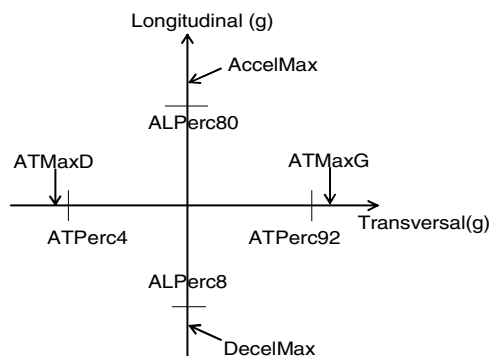


Figure 10. acceleration variables

STATISTIC TEST

To study the difference in the use (driving) of the 2 cars by the 36 volunteers, the eleven variables described above are chosen (Figure 11). **Pink lines mean subjects of group 1** and **black lines mean subjects of group 2**. **Red lines mean characteristic values of Group 1** and **Blue lines mean those of Group 2**. **Bold lines mean average value** of each group, dotted lines mean plus (minus) of variance value of each group.

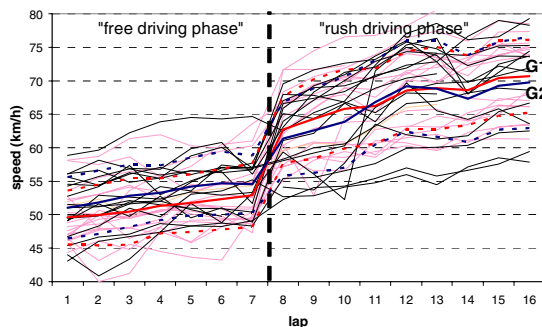


Figure 11. Example data of each variable

Data selection

To eliminate bias due to stabilized / not stabilized driving rhythm, it was decided for the two driving phases ("free" and "rush") that statistical tests are systematically conducted using, in one case all the data collected in all laps, and in the other case only the data on last laps: the 4 last laps for "free driving phase", the 3 last laps for "rush driving phase".

Statistic method

Generally speaking, to compare performance of two cars, comparison of mean is common. This method is largely divided into two parts: nonparametric and parametric ANOVA. Parametric method is used when data are normally distributed, otherwise nonparametric method is recommendable. To characterize the type of data distribution (normality test), "Kolmogorov-Smirnov test" and "Shapiro-Wilk test¹" were used.

If data are normally distributed, repeated ANOVA is used. Otherwise, after Mann-Whitney test for each lap is executed, all significances of each lap are integrated. Integrated level is made using the following formula:

$$\text{Integrated p-value} = 1 - (1 - P_1) \cdot (1 - P_2) \cdot \dots \cdot (1 - P_n)$$

where p-value corresponds to the Mann-Whitney test result when comparing recent car with old one.

Lap (test track)	1	2	...	n
p-value	P ₁	P ₂	...	P _n

RESULTS

Graphs

Following graphs give a comparison between the real use of the two cars, in the two driving phases, and for the eleven variables:

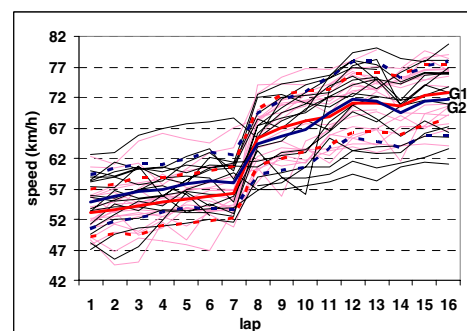


Figure 12. VmoyTour

¹ Shapiro-Wilk test is appropriate when the number of total population is less than 50.

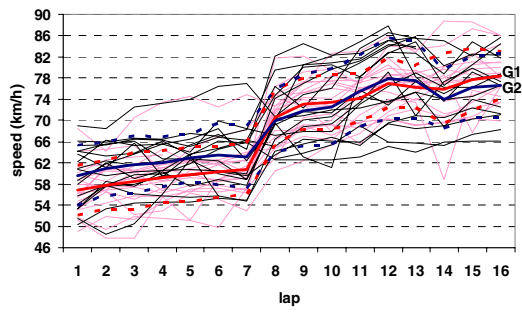


Figure 13. VmoyLD

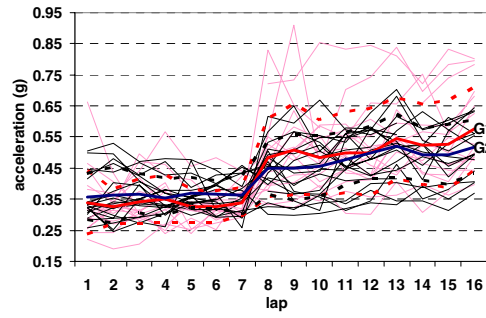


Figure 18. DecelMax

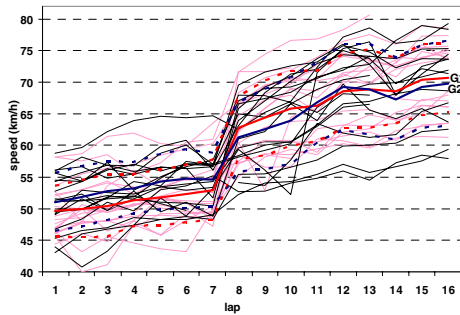


Figure 14. VmoyVG

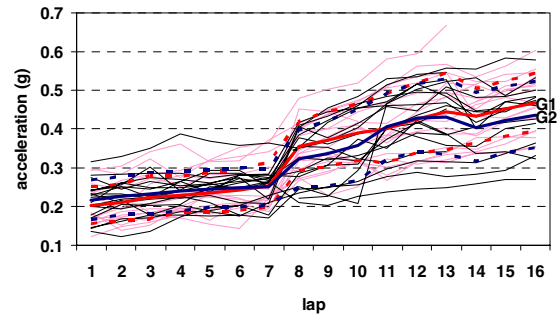


Figure 19. ATPerc92

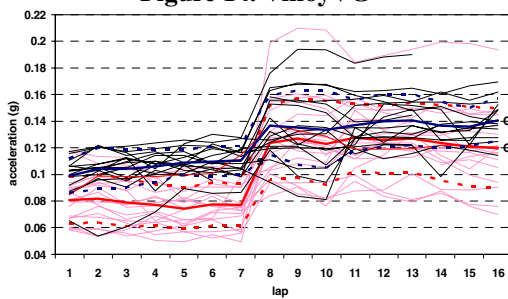


Figure 15. ALPerc80

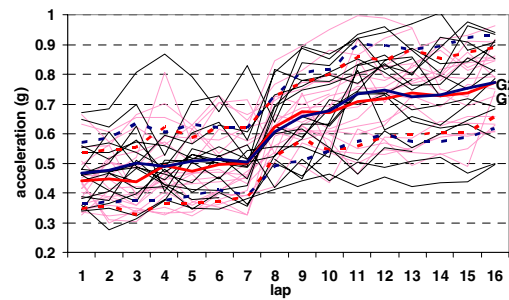


Figure 20. ATMaxG

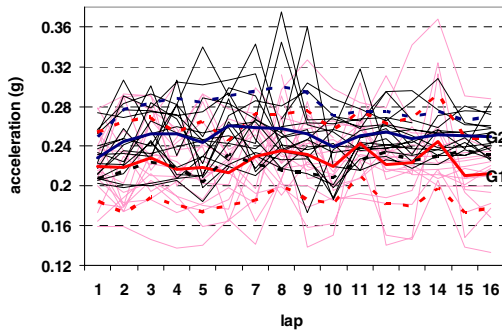


Figure 16. AccelMax

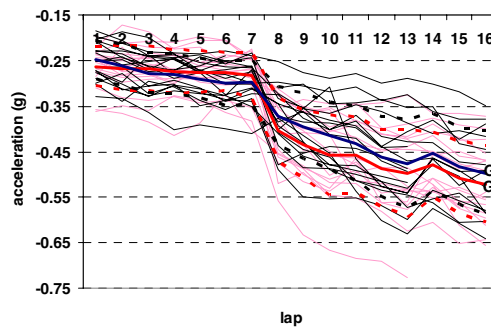


Figure 21. ATPerc4

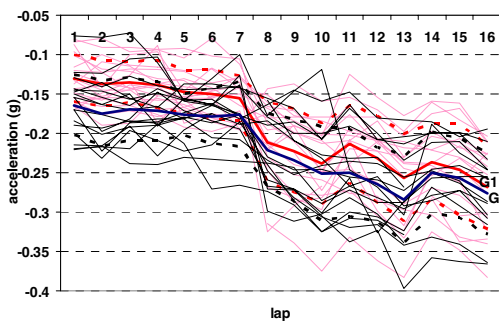


Figure 17. ALPerc8

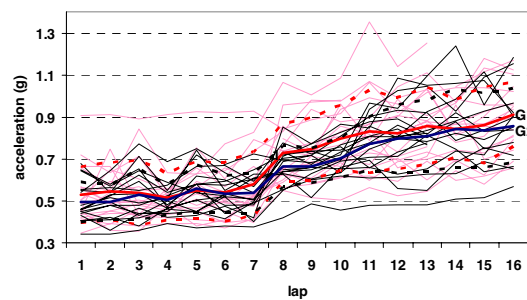


Figure 22. ATMaxD

Statistical Results

If p-value is less than 0.05 (significance level), there is significant difference between the 2 groups of drivers. In **Table 3**, results are described:

Table 3.
p-value of each variable

Variable	p-value of free driving phase		p-value of rush driving phase	
	With all data (all laps)	With 4 last laps data	With all data (all laps)	With 3 last laps data
Vmoy	.656*	.457*	.999*	.570
VmoyLD	.075	.086	.561	.380
VmoyVG	.729*	.487*	.999*	.952*
ALPerc80	.002*	.000	.722*	.069
AccelMax	.547*	.196	.692*	.100*
ALPerc8	.248	.516	.386	.556
DecelMax	.992*	.980*	.999*	.979*
ATPerc92	.996*	.980*	.480	.290
ATMaxG	.999*	.996*	.999*	.887
ATPerc4	.986*	.883*	.413	.401
ATMaxD	.999*	.999*	.514	.647

* means nonparametric repeated ANOVA

- Average speed: in the 2 driving phases, there is no significant difference on drivers' behavior between old and recent car for the three speed variables (all the lap, straight lines only, curves only). That is, we can not say that drivers in the recent car tend to drive faster than those in old car. For the three last laps of phase1, the average of speed of Group 1 is 55.3, 55.8 and 56.4 km/h while 57.8, 58.3 and 58.1 km/h in Group 2 (Table 4).
- Longitudinal acceleration: in both phases, there is no significant difference between two cars in AccelMax. The only significant difference between these cars is observed in ALPerc80 parameter (which could be explained by certain differences in performance between two cars?) in free driving phase, but it is not the case in rush driving phase. For example, for the three last laps of "free phase", the average of 80 percentile of acceleration of G1 was 0.074g, 0.078g and 0.077g while 0.109g, 0.109g and 0.110g in G2 (Table 4). It is also interesting to note that for the two cars, there is no significant difference on maximum acceleration between the two driving phases. This could be explained by car acceleration "limit" (depending especially on the engine power).
- Longitudinal deceleration: both DecelMax and ALPerc8 have no significant difference between the 2 groups in both phases, despite the difference between braking systems of the 2 cars. For the three last laps of phase 1, the average of 8 percentile of acceleration of G1 was -0.148g, -0.150g and -0.156g while -0.176g, -0.178g and -0.176g in G2 (Table 4).

- Transversal acceleration: In both phases, there was no significant difference between two cars in all transversal acceleration variables. For example, for the three last laps of phase1, the average of 92 percentile of lateral acceleration of G1 was 0.234g, 0.243g and 0.254g. Those of G2 were 0.245g, 0.249g and 0.249g (Table 4).

Table 4.
Average values of free driving phase

Variable	Group	"Free driving phase"			
		4th	5th	6th	7th
VmoyTour (km/h)	1	54.9	55.3	55.8	56.4
	2	57.0	57.8	58.3	58.1
VmoyLD (km/h)	1	59.3	59.7	60.3	60.9
	2	62.1	62.8	63.5	63.1
VmoyVG (km/h)	1	51.3	51.7	52.3	52.9
	2	53.3	54.2	54.7	54.6
ALPerc80 (g)	1	.077	.074	.078	.077
	2	.106	.109	.109	.110
AccelMax (g)	1	.217	.219	.213	.229
	2	.253	.243	.261	.258
ALPerc8 (g)	1	-.138	-.148	-.150	-.156
	2	-.172	-.176	-.178	-.176
DecelMax (g)	1	.351	.325	.326	.340
	2	.355	.371	.365	.363
ATPerc92 (g)	1	.230	.234	.243	.254
	2	.240	.245	.249	.249
ATMaxG (g)	1	.492	.473	.495	.501
	2	.490	.509	.514	.506
ATPerc4 (g)	1	-.274	-.275	-.275	-.283
	2	-.279	-.291	-.300	-.297
ATMaxD (g)	1	.552	.543	.579	.579
	2	.558	.532	.537	.537

Table 5.
Average values of rush driving phase

variable	group	"Rush driving phase"		
		7th	8th	9th
VmoyTour (km/h)	1	70.6	72.4	72.8
	2	69.5	71.4	71.8
VmoyLD (km/h)	1	76.0	77.8	78.4
	2	74.0	76.3	76.6
VmoyVG (km/h)	1	68.6	70.4	70.7
	2	67.3	69.3	69.8
ALPerc80 (g)	1	.124	.120	.120
	2	.136	.136	.141
AccelMax (g)	1	.245	.210	.212
	2	.252	.250	.250
ALPerc8 (g)	1	-.237	-.247	-.268
	2	-.250	-.257	-.277
DecelMax (g)	1	.524	.526	.576
	2	.492	.492	.517
ATPerc92 (g)	1	.434	.451	.469
	2	.404	.422	.436
ATMaxG (g)	1	.727	.737	.772
	2	.731	.754	.772
ATPerc4 (g)	1	-.479	-.508	-.521
	2	-.452	-.482	-.497
ATMaxD (g)	1	.842	.862	.912
	2	.843	.836	.858

DISCUSSION

With this macroscopic analysis level, we didn't demonstrate significant differences in the use of the two different cars, except in maximum longitudinal accelerations. However, the comparison between average speed in straight lines is at the limit of the statistical significance ($p=0.08$) which could be explained by the probable quite difference between car's performances. This result must be relativized: no significant difference between average speed in the curves of the test track. In addition, it is possible that the presence of an experimenter next to the driver in the vehicle, especially in rush phase, can induce an over-confidence, and maybe unmeasured objective risk.

It is probable that representation of everyone when driving a car for the first time is confirmed or infirmed, positively or negatively, with the experience (driving). It seems among this study that driver, even if he drives a new modern car with more assistance systems (vehicle chassis, soundproofing, braking) and a better external aspect, (aerodynamic shape, dimension of the tires...) than old vehicle, he does not have systematically a different behavior in both, normal (free phase) and hurry driving (rush phase). We can assume that global representation before and during driving would mostly condition his behavior adaptation (with a more or less risk taking) more than his just awareness about this or that assistance. These interpretations are based in a great part on the exploitation of the interviews with the psychologist at the end of the driving tasks. For example: from the interview with the psychologist at the end of "rush driving phase", some drivers were very surprised (positively) by the road handling of the old car, which is opposite to what they supposed it to be before driving. But of course, in all cases, the driving profile or style ("slow", "normal" or "active") has also an evident influence on the use of the vehicle, independently of its characteristics.

As in any test track experiment, some bias can not be avoided. People don't drive their own cars, they are asked to drive "freely" or "in a hurry" with an experimenter in the car, on a test track they don't know. The "free" phase is very important: subjects take one hour to "test" the vehicle, to memorize the road and its environment, and also to discuss a little with their passenger. We can assume that these bias will decrease with time (or laps), and drivers will use their own driving habitudes as in real road.

In this paper, guidelines about drivers' behavior are presented. There is a probability to be exaggerated in some variables in rush driving phase. Generally people drive their own cars with more care because they don't want to change regularly car accessories (like tires or brakes) nor losing money because fuel consummation.

The result of this pilot experiment on the effect of car improvements must be taken with care regarding to its limits: representativity of drivers (especially their number) and the test track (in terms of geometry, state of the road...), lack of traffic...

The LAB conducted in 2003 another experiment with 83 drivers on a 50 km real road including highways and secondary roads. Subjects drove a Peugeot 307 vehicle. Even experimental protocol is different from the present study, it is interesting to observe that the medians of maximum transversal acceleration are quite similar: 0.55 g against 0.59 g respectively (Figure 23).

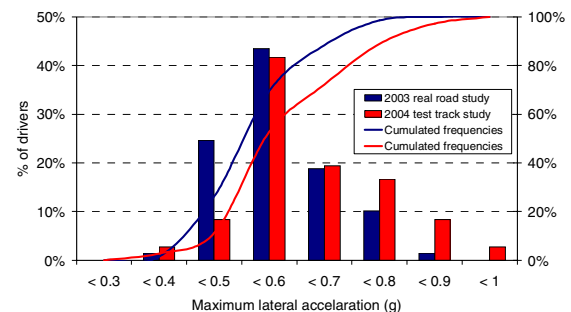


Figure 23. Comparison with another study

CONCLUSION

In the respect of longitudinal acceleration, there is significant difference between the use of the 2 cars in 80 percentile of longitudinal acceleration (ALPerc80) by the 2 groups in "free driving phase", but not in "rush phase". However, there is no significant difference between general driving behavior of the 2 groups in speed variables and transversal acceleration variables.

To analyze this part, deeper inspection is necessary. In addition, big dispersion between the drivers, even in the same Group, are observed at least on the eleven variables analyzed in this paper.

This study using general or macroscopic variables such as average speed per lap must be continued by a more detailed or microscopic analysis of the driver behavior and his strategies when negotiating some particular curves for example.

This study was conducted for instance only with objective variables. Further analysis will integrate subjective data collected by the psychologist at the end of all driving tasks. This would give relevant information about the real use of the vehicles and how drivers perceive/choose the level of solicitations in the two driving tests, and also a comparison between the two cars

Despite the lack of quantitative studies on the effect of cars' improvements, and even if some active safety devices or any other driver assistances would change their driving behavior, it must be kept in mind that improvements in passive safety by reducing the number of injuries today allow an

important compensation of any perverse effect of assistances.

The first macroscopic results of this study on behavior adaptation to car's improvements shows the interest of focusing on the global representation of the car than on an isolated effects of this or that assistance.

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REFERENCES

[1] Stein Fosser, Fridulv Sagberg, and Inger Anne F. Stætermo, 1996. "Behavioral adaptation to airbags and antilock brakes", Nordic Road & Transport Research, No. 3
(<http://www.drivers.com/article/326/>)

[2] Chanton, O., Sauvage, J., Kassaagi, M., Coratte, J.-F., 2002. Study of car loss of control : a comparison between an experiment on the dynamic simulator of Renault and a test track study, Driving Simulation Conference, DSC'2002, Paris

[3] SETRA 2002, Service d'Etudes Techniques des Routes et Autoroutes, France